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Forecasting TB Incidence in India Using the Multilayer Perceptron Neural Network

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***Abstract* - India has a population of about 1.2 billion and is one of the Asian nations with a high TB disease burden. Modeling TB incidence is very important in order to assess the impact of TB control measures in the country. In this research article, the ANN approach was applied to analyze TB incidence in India. The employed annual data covers the period 2000-2018 and the out-of-sample period ranges over the period 2019-2023. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting TB incidence in India. The results of the study indicate that TB incidence will remain high although a slight decrease is expected from 198 cases/100 000/year in 2019 to 198 cases/100 000/year in 2023. Therefore, the Indian government is encouraged to intensify TB surveillance and control programs despite the fact that it is currently battling COVID-19. If the government becomes complacent in the Control of TB, the country is likely to see a sharp increase in new TB cases hence increase in TB incidence over the period 2021-2023.**

Keywords: ANN, Forecasting, TB incidence.

I. INTRODUCTION

India is one of the countries in the World with a high TB incidence. Six countries namely Indonesia, China, Nigeria, Pakistan, South Africa together with India contributes around 60% of the total TB incidence in the World (WHO, 2016). WHO reported that in 2015, the incidence of TB in India was around 217 per 100 000 population and a high mortality of around 19 per 100 000 people. Following the adoption of Directly observed treatment short course (DOTS) strategy India began to see a significant decline in mortality due to TB. In 2013 the country noted that mortality due to TB had reduced by 50% in comparison with 1990 (Ministry of health and Family Welfare, 2015). TB is caused by mycobacterium tuberculosis and its mode of transmission is airborne via coughing and sneezing. Previous studies have shown that malnutrition, deprivation, poverty and overcrowding are among the risk factors of getting TB. This clearly explains why developing nations have a high incidence of TB as compared with developed ones (Lienhardt et al, 2001; Rieder, 1999). Furthermore studies in the past have revealed that immune compromised patients are also at risk of developing TB (WHO, 2018). TB remains a global health challenge particularly with the emergence of multi-drug resistant TB (MDR-TB), extensively drug resistant TB (XDR-TB) and the totally resistant (TDR) strains together with TB/HIV co-infection especially in developing countries (WHO, 2010).

There are few empirical studies on TB that were carried out in India.Patowary &Barman (2017) developed a SARIMA model to forecast TB detection rate in Dibrugarh in Assam District of India using historical data covering the period 2001-2011.The study concluded that the SARIMA (0,0,0) x (1,1,0)4 was suitable for the given data set. Varun et al (2014) conducted a retrospective record-based study in a DOTS Centre in South district of Dehli.The data covering the period January 2007 to December 2012 was analyzed using SPSS version 2.1software. The research concluded that a seasonal pattern and declining trend with variable amplitudes of fluctuation were observed in the incidence of TB.This study aims to model and forecast the incidence of TB using the multilayer peceptron, ANN (9,12,1) model. Proper estimation and projection of the burden of TB is necessary for appropriate control of the disease. The findings from this paper will trigger an early response to the epidemic so that timeous and correct measures are implemented.

II. METHOD

The Artificial Neural Network (ANN), which we are going to apply; is a data processing system consisting of a large number of simple and highly interconnected processing elements resembling a biological neural system. It has the capability of learning from an experimental or real data set to describe the nonlinear and interaction effects with great accuracy. ANN-based curve fitting technique is one of the extensively applied artificial intelligence methods that are used for forecasting and prediction

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purpose. It consists of basically three layers i.e., input layer, hidden layer, and output layer, the present work includes the number of years as input layer and the annual TB incidence in India as output data for the network. In this paper, our ANN is based on the hyperbolic tangent function.

Data Issues

This study is based on TB incidences (referred to as T series in this study) in India. The annual data covers the period 2000-2018 while the out-of-sample forecast covers the period 2019-2023. All the data employed in this research paper was gathered from the World Bank online database.

III. FINDINGS OF THE STUDY

DESCRIPTIVE STATISTICS

Table 1: Descriptive statistics

Mean	Median	Minimum	Maximum
251.11	254.00	199.00	289.00
Std. Dev.	C.V.	Skewness	Ex. kurtosis
31.023	0.12355	-0.25228	-1.3529
5% Perc.	95% Perc.	IQ range	Missing obs.
undefined	289.00	59.000	0

ANN MODEL SUMMARY FOR TB INCIDENCE (new cases per 100 000 population /year) IN INDIA

Table 2: ANN model summary

Variable	T
Observations	10 (After Adjusting Endpoints)
Neural Network Architecture:	
Input Layer Neurons	9
Hidden Layer Neurons	12
Output Layer Neurons	1
Activation Function	Hyperbolic Tangent Function
Back Propagation Learning:	
Learning Rate	0.005
Momentum	0.05
Criteria:	
Error	0.008736
MSE	0.190804
MAE	0.404408

Residual Analysis for the ANN model

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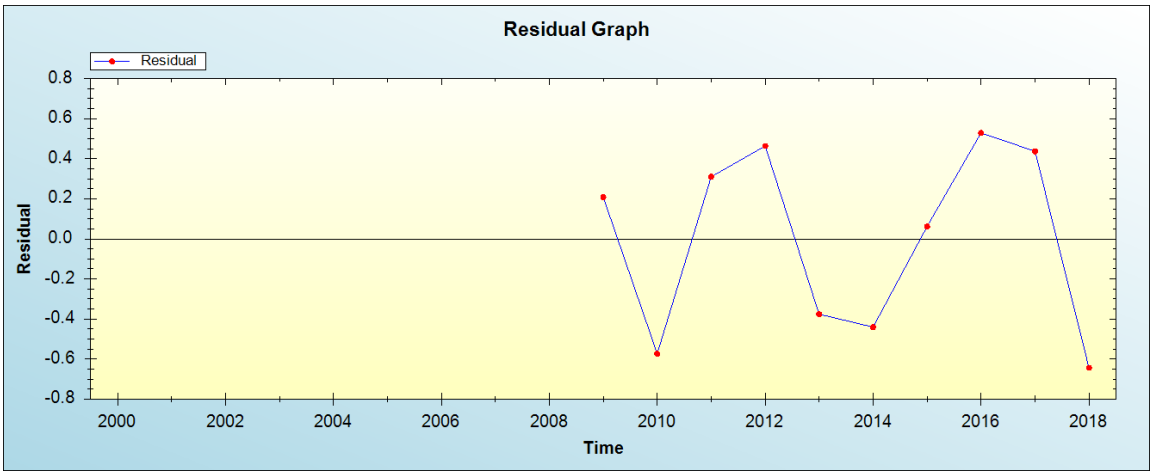

Figure 1: Residual analysis

In-sample Forecast for T

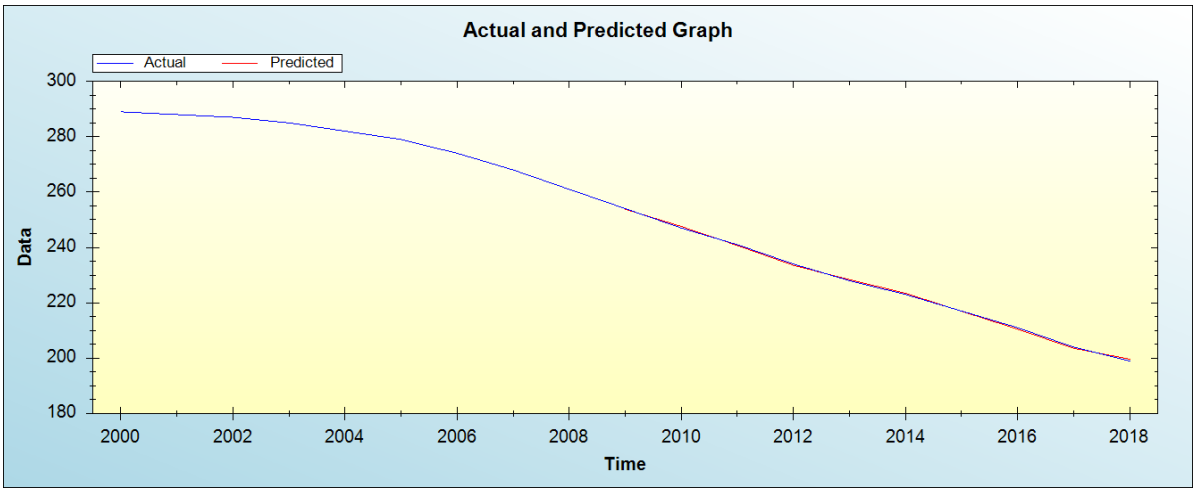

Figure 2: In-sample forecast for the T series

Figure 2 shows the in-sample forecast for T series.

Out-of-Sample Forecast for T: Actual and Forecasted Graph

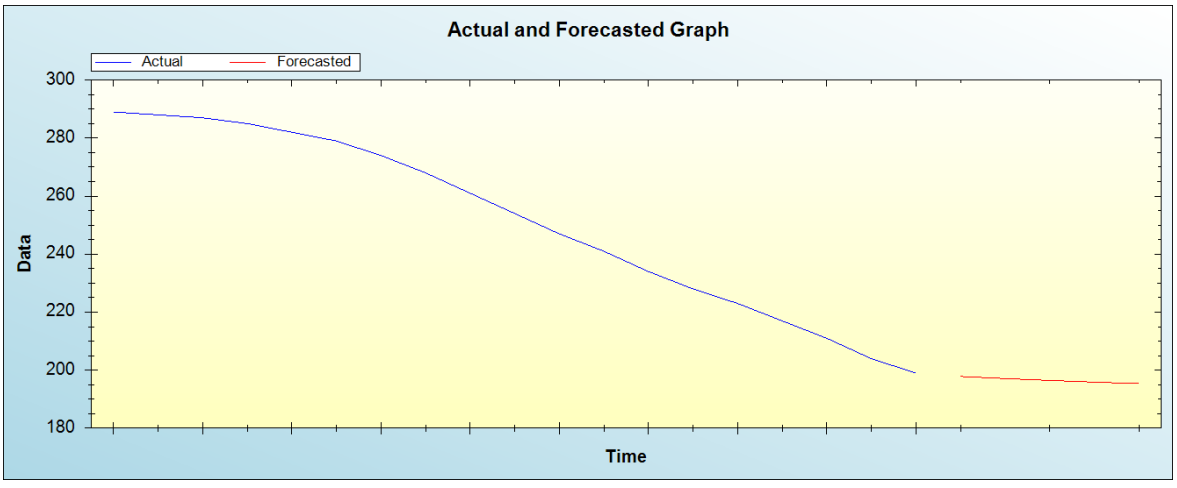

Figure 3: Out-of-sample forecast for T: actual and forecasted graph

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Out-of-Sample Forecast for T: Forecasts only

Table 3: Tabulated out-of-sample forecasts

Year	Forecasts
2019	197.8698
2020	197.1265
2021	196.4734
2022	195.8964
2023	195.4116

Over the study period 2000-2018 the TB incidence has been gradually decreasing and characterized by an average incidence of 251 cases per 100 000 population/year. The minimum and maximum TB incidence was 199 and 289 cases per 100 000 population/year respectively. The applied data is not normally distributed because it is negatively skewed and platykurtic. The residual graph and model evaluation criteria (ERROR, MSE, MAE) suggest that the applied ANN (9,12,1) model is stable and suitable for forecasting TB incidence in India. In-sample forecasts reveal that the applied model simulates the observed data very well. The model predicts that over the period 2019-2023 TB incidence will slightly decrease from around 198 (in 2019) to around 195 cases per 100 000 population /year in 2023 and will remain high.

IV. CONCLUSION & RECOMMENDATIONS

India is one the countries in the World with a high TB disease burden partly due to overcrowding and poverty. Figure 3 shows that the country has done very well in the control the TB epidemic over the period 2000-2018 as this period was characterized by a significant decline in the incidence of TB. It means the government has implemented robust control measures to curb the spread of the disease. Despite all these efforts model predictions suggest that the incidence of TB will remain high over the period 2019-2023.Therefore the government of India should not relax in the prevention and control of TB. Currently the nation is battling COVID-19 and if the government shifts its focus from HIV/TB programs towards COVID-19 pandemic the country is likely to experience a sharp increase in the number of new TB cases over the period 2019-2023.The government should strengthen TB /HIV program collaboration and intensify TB surveillance and control.

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